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☐ 1. Document ID: US 6219571 B1 Relevance Rank: 72

L6: Entry 1 of 5 File: USPT Apr 17, 2001

US-PAT-NO: 6219571
DOCUMENT-IDENTIFIER: US 6219571 B1

TITLE: Magnetic resonance imaging using driven equilibrium fourier transform

DATE-ISSUED: April 17, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Hargreaves; Brian A.	Stanford	CA		
Nishimura; Dwight G.	Palo Alto	CA		

ASSIGNEE-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY	TYPE CODE
Board of Trustees of the Leland Stanford Junior University	Palo Alto	CA			02

APPL-NO: 9/ 280223
DATE FILED: March 29, 1999

PARENT-CASE:
This application is a continuation of and claims the benefit of U.S. Provisional Application No. 60/080,904 filed Apr. 6, 1998, the disclosure of which is incorporated by reference.

INT-CL: [7] A61B 5/055
US-CL-ISSUED: 600/410; 324/307, 324/309
US-CL-CURRENT: 600/410; 324/307, 324/309
FIELD-OF-SEARCH: 600/410, 324/307, 324/309

PRIOR-ART-DISCLOSED:

U.S. PATENT DOCUMENTS

PAT-NO	ISSUE-DATE	PATENTEE-NAME	US-CL
4165479	August 1979	Mansfield	324/309
4509015	April 1985	Ordidge et al.	324/309
4532474	July 1985	Edelstein	324/309
4665365	May 1987	Glover et al.	324/309
4766381	August 1988	Conturo et al.	324/309
4893081	January 1990	Zur	324/309
5245282	September 1993	Mugler, III et al.	324/309
5303705	April 1994	Nenov	600/410

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Shoup, R.R. et al., "The Driven Equilibrium Fourier Transform NMR Technique: An Experimental Study," Journal of Magnetic Resonance 8, 298-310 (1972).
Iwaoka, Hideto et al., "A New Pulse Sequence for "Fast Recovery" Fast-Scan NMR Imaging," IEEE Transactions on Medical Imaging, vol. MI-3, No. 1, pp. 41-46, Mar. 1984.
Van Uijen, C.M.J. et al., "Driven-Equilibrium Radiofrequency Pulses in NMR Imaging," Magnetic Resonance in Medicine I, 502-507 (1984).
Maki, J.H. et al., "SNR Improvement in NMR Microscopy Using DEFT," Journal of Magnetic Resonance 80, 482-492 (1988).
Rubenstein, Joel D. et al., "Image Resolution and Signal-to-Noise Ratio Requirements for MR Imaging of Degenerative Cartilage," AJR:169, , pp. 1089-1096, Oct. 1997.
Yao, Lawrence et al., "MR Imaging of Joints: Analytic Optimization of GRE Techniques of 1.5 T," AJR:158, pp 339-343 Feb. 1992.
Brittain, Jean H. et al., "Coronary Angiography with Magnetization-Prepared T.sub.2 Contrast," MRM, 33:689-696 (1995).
Henkelman, R.Mark et al., "Anisotropy of NMR Properties of Tissues," MRM 32:592-601 (1994).
Recht, Michael P. et al., "MR Imaging of Articular Cartilage: Current Status and Future Directions," AJR:163-283-290 (1994).
Peterfy, Charles G., et al., "MR Imaging of the Arthritic Knee: Improved Discrimination of Cartilage, Synovium, and Effusion with Pulsed Saturation Transfer and Fat-suppressed T1-weighted Sequences," Radiology 191:413-419 (1994).

ART-UNIT: 377
PRIMARY-EXAMINER: Casler; Brian L.
ATTY-AGENT-FIRM: Townsend and Townsend and Crew LLP Woodward; Henry K.

ABSTRACT:

A new technique for imaging a material with a high T2/T1 ratio such as articular cartilage uses driven equilibrium Fourier transform (DEFT), a method of enhancing signal strength without waiting for full T1 recovery. Compared to other methods, DEFT imaging provides a good combination of bright cartilage and high contrast between cartilage and surrounding tissue. Both theoretical predictions and images show that DEFT is a valuable method for imaging articular cartilage when compared to spoiled gradient recalled acquisition in the steady-state (SPGR) or fast spin echo (FSE). T2-decay, T1 recovery, echo time, magnetization density, proton density, and equilibrium density per proton are related by a derived equation.

16 Claims, 22 Drawing figures

☐ 2. Document ID: US 5825185 A Relevance Rank: 54

L6: Entry 2 of 5 File: USPT Oct 20, 1998

US-PAT-NO: 5825185
DOCUMENT-IDENTIFIER: US 5825185 A

TITLE: Method for magnetic resonance spin echo scan calibration and reconstruction

DATE-ISSUED: October 20, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Liu; Haiying	Minneapolis	MN		
Bearden; Francis H.	Twinsburg	OH		
DeMeester; Gordon D.	Wickliffe	OH		

ASSIGNEE-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY	TYPE CODE
Picker International, Inc.	Highland Heights	OH			02

APPL-NO: 8/ 757153
DATE FILED: November 27, 1996

INT-CL: [6] G01V 3/00
US-CL-ISSUED: 324/309; 324/307
US-CL-CURRENT: 324/309; 324/307
FIELD-OF-SEARCH: 324/309, 324/307, 324/306, 324/314, 324/300, 324/312

PRIOR-ART-DISCLOSED:

U.S. PATENT DOCUMENTS

PAT-NO	ISSUE-DATE	PATENTEE-NAME	US-CL
4851779	July 1989	DeMeester et al.	324/309
5138259	August 1992	Schmitt et al.	324/309
5581184	December 1996	Heid	324/309
5621321	April 1997	Liu et al.	324/307
5742163	April 1998	Liu et al.	324/309

FOREIGN PATENT DOCUMENTS

FOREIGN-PAT-NO	PUBN-DATE	COUNTRY	US-CL
0296834A3	December 1988	EPX	
0296834A2	December 1988	EPX	
0490528A1	June 1992	EPX	
0772057A1	July 1997	EPX	
4005675A1	August 1991	DEX	
4445782C1	July 1996	DEX	

OTHER PUBLICATIONS

Hennig, J., et al. "RARE Imaging: A Fast Imaging Method for Clinical MR," Mag. Res. Med., 3, pp. 823-833 (1986).
Mulkern, R.V., et al., "Contrast Manipulation and Artifact Assessment of 2D and 3D Rare Sequences," Mag. Res. Imaging, 8, pp. 557-566 (1990).
Zhou, et al., "On Phase Artifacts of High-Field Fast Spin-Echo Images," SMRI Abstract Book, p. 1248 (Aug. 1993).
Zhou, et al., "Reduction of Ringing and Blurring Artifacts in Fast Spin-Echo Images," SMRI Abstract Book, p. 935 (Aug. 1993).
Zhou, et al., "Reduction of Ringing and Blurring Artifacts in Fast Spin-Echo Images," J. Mag. Res. Imaging, 3, pp. 803-807 (Sep./Oct. 1993).
Wan, et al., "Reduction of Phase Error Ghosting Artifacts in Thin Slice Fast Spin-Echo Imaging," Mag. Res. Med., 34, pp. 632-638 (1995).
Press, et al. "Numerical Recipes in Fortran: The Art of Scientific Computing,"2nd. ed. (1992).
XP002057350 2D Phase Correction For Multiple Shot EPI, Haiying Liu, et al. Proceedings International Society Magnetic Resonance Medicine, vol. 3.
XP002057349 Cross-Correlation in MRI: Image Reg., P.V. Connaughton, et al. Book of Abstracts vol. 2, Society Magnetic Resonance Medicine and Biology.

ART-UNIT: 287
PRIMARY-EXAMINER: Arana; Louis M.
ATTY-AGENT-FIRM: Fay, Sharpe, Beall, Fagan, Minnich & McKee

ABSTRACT:

A transmitter (24) and gradient amplifiers (20) transmit radio frequency excitation and other pulses to induce magnetic resonance in selected magnetic dipoles and cause the magnetic resonance to be focused into a series of echoes (66) at each of a plurality of preselected echo positions following each excitation. A receiver (38) converts each echo into a data line. Calibration data lines having a close to zero phase-encoding are collected and used to generate correction parameters (102) for each of the echo positions. These parameters include relative echo center positions (96) and unitary complex correction vectors (106). The calibration data lines for each of the preselected positions are one-dimensionally Fourier transformed (82) and multiplied (90) by the same complex conjugate reference echo (80). These data lines are then inverse Fourier transformed (92) to generate an auxiliary data array (94). A relative echo center position is computed (96) which represents a fractional shift of the true center relative to the reference echo. A complex sum is computed (104) from the relative echo center position and normalized (106) to generate a unitary correction vector. The phase-correction parameters are used to phase-correct (116) imaging data lines. The phase-corrected imaging data lines are sorted (122) to build an image plane which is one-dimensionally Fourier transformed (128) in the phase-encoding direction to produce a final corrected image (130) for display on a monitor (134).

18 Claims, 7 Drawing figures

Full | Title | Citation | Front | Review | Classification | Date | Reference KWIC | Draw Desc | Image

3. Document ID: US 5245282 A Relevance Rank: 53

L6: Entry 5 of 5 File: USPT Sep 14, 1993

US-PAT-NO: 5245282
DOCUMENT-IDENTIFIER: US 5245282 A

TITLE: Three-dimensional magnetic resonance imaging

DATE-ISSUED: September 14, 1993

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Mugler, III; John P.	Charlottesville	VA		
Brookeman; James R.	Charlottesville	VA		

ASSIGNEE-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY	TYPE CODE
University of Virginia Alumni Patents Foundation	Charlottesville	VA			02

APPL-NO: 7/ 723230
DATE FILED: June 28, 1991

INT-CL: [5] G01R 33/20
US-CL-ISSUED: 324/309
US-CL-CURRENT: 324/309
FIELD-OF-SEARCH: 324/300, 324/307, 324/309, 324/312, 324/318, 324/322, 128/653.2

PRIOR-ART-DISCLOSED:

U.S. PATENT DOCUMENTS

PAT-NO	ISSUE-DATE	PATENTEE-NAME	US-CL
4797616	January 1989	Matsui et al.	324/309
4801884	January 1989	Oppelt et al.	324/309
4818942	April 1989	Rzedzian	324/312
4830012	May 1989	Riederer	128/653
4833407	May 1989	Holland et al.	324/309
4836209	June 1989	Nishimura	128/653
4843321	June 1989	Sotak	324/309
4856528	August 1989	Yang et al.	128/653
4895157	January 1990	Nambu	128/653
4901019	February 1990	Wedeen	324/309
4940941	July 1990	Rzedzian	324/312
4982161	January 1991	Twieg	324/309
4984573	January 1991	Leunbach	128/653
4986272	January 1991	Riederer et al.	128/653
4991586	February 1991	Mueller et al.	128/653
4993075	February 1991	Sekihara et al.	382/6K
5072182	December 1991	Derby et al.	324/309
5084675	January 1992	Reinfelder et al.	324/309
5087880	February 1992	Bruder et al.	324/309
5105152	April 1992	Pauly	324/309
5122747	June 1992	Reiderer et al.	324/309

ART-UNIT: 263
PRIMARY-EXAMINER: Tokar; Michael J.
ATTY-AGENT-FIRM: Parker; Sheldon H.

ABSTRACT:

A new three-dimensional (3D) MR imaging pulse sequence can produce over 100 high-resolution, high-contrast images in as little as 6 minutes of imaging time. Without additional imaging time, this same image data can be post-processed to yield high-resolution, high-contrast images in any arbitrary orientation. Thus, this new pulse sequence technique provides detailed yet comprehensive coverage. The method of this invention relates to a preparation-acquisition-recovery sequence cycle. The first step is magnetization preparation (MP) period. The MP period can emply a series of RF pulses, gradient field pulses, and/or time delays to encode the desired contrast properties in the form of longitudinal magnetization. A data acquisition period includes at least two repetitions of a gradient echo sequence to acquire data for a fraction of k-space. A magnetization recovery period is provided which allows T1 and T2 relaxation before the start of the next sequence cycle. The MP, data acquisition and magnetization recovery steps are repeated until a predetermined k-space volume is sampled.

44 Claims, 6 Drawing figures

Full | Title | Citation | Front | Review | Classification | Date | Reference | KWIC | Draw. Desc | Image

☐ 4. Document ID: US 5742163 A Relevance Rank: 53

L6: Entry 3 of 5 File: USPT Apr 21, 1998

US-PAT-NO: 5742163
DOCUMENT-IDENTIFIER: US 5742163 A

TITLE: Magnetic resonance scan calibration and reconstruction technique for

multi-shot, multi-echo imaging

DATE-ISSUED: April 21, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Liu; Haiying	Euclid	OH		
DeMeester; Gordon D.	Wickliffe	OH		
McNally; James M.	Chagrin Falls	OH		

ASSIGNEE-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY	TYPE CODE
Picker International, Inc.	Highland Heights	OH			02

APPL-NO: 8/ 638643
DATE FILED: April 26, 1996

INT-CL: [6] G01V 3/00
US-CL-ISSUED: 324/309; 324/307
US-CL-CURRENT: 324/309; 324/307
FIELD-OF-SEARCH: 324/309, 324/307, 324/306, 324/314, 324/312, 324/300, 128/653.2

PRIOR-ART-DISCLOSED:

U.S. PATENT DOCUMENTS

PAT-NO	ISSUE-DATE	PATENTEE-NAME	US-CL
5151656	September 1992	Maier et al.	324/309
5531223	July 1996	Hatanaka	324/309
5557204	September 1996	Lenz	324/309
5581184	December 1996	Heid	324/309
5652514	July 1997	Zhang et al.	324/309

FOREIGN PATENT DOCUMENTS

FOREIGN-PAT-NO	PUBN-DATE	COUNTRY	US-CL
0 250 050	December 1987	EPX	
0 280 310	August 1988	EPX	

OTHER PUBLICATIONS

"Cartesian Echo Planar Hybrid Scanning with Two to Eight Echoes", Kashmar, et al. IEEE Trans on Medical Imaging, V. 10, N. 1, Mar. 1991.
"Interleaved Echo Planar Imaging on a Standard MRI System", Butts, et al. MRM 31:677-72 (1994).
"Ultrafast Interleaved Gradient-Echo-Planar Imaging on a Standard Scanner", McKinnon, MRM 30:609-616 (1993).

ART-UNIT: 225
PRIMARY-EXAMINER: Arana; Louis M.
ATTY-AGENT-FIRM: Fay, Sharpe, Beall, Fagan, Minnich & McKee

ABSTRACT:

A sequence control (40) causes a transmitter (24) and gradient amplifiers (20) to transmit radio frequency excitation and other pulses to induce magnetic resonance in selected dipoles and cause the magnetic resonance to be focused into a series of echoes in each of a plurality of data collection intervals following each excitation. A receiver (38) converts each echo into a data line. Calibration data lines having a close to zero phase-encoding are collected during each of the data collection intervals. The calibration data lines in each data collection interval

are zero-filled (86) to generate a complete data set and Fourier transformed (88) into a series of low resolution complex images (90.sub.1, 90.sub.2, . . . 90.sub.n), each corresponding to one of the data collection intervals. The low resolution images are normalized (92) and their complex conjugates taken (94). Imaging data lines are sorted by a data collection interval and zero-filled (104) to create full data sets. The full data set corresponding to each data sampling interval is Fourier transformed into partial image representations (106.sub.1, 106.sub.2, 106.sub.n). Each partial image is multiplied (108) by a complex conjugate of the normalized phase correction map (96) to create corrected partial images which are summed (112) to generate a composite image (114). The composite images are density corrected (120).

20 Claims, 11 Drawing figures

☐ 5. Document ID: US 5285158 A Relevance Rank: 50

L6: Entry 4 of 5 File: USPT Feb 8, 1994

US-PAT-NO: 5285158
DOCUMENT-IDENTIFIER: US 5285158 A

TITLE: NMR angiography using fast pulse sequences with preparatory pulses

DATE-ISSUED: February 8, 1994

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Mistretta; Charles A.	Madison	WI		
Korosec; Frank R.	Madison	WI		
Weber; David M.	Middleton	WI		
Grist; Thomas M.	Madison	WI		

ASSIGNEE-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY	TYPE CODE
Wisconsin Alumni Research Foundation	Madison	WI			02

APPL-NO: 7/ 926658
DATE FILED: August 6, 1992

INT-CL: [5] G01R 33/70
US-CL-ISSUED: 324/309; 324/306, 128/653.3
US-CL-CURRENT: 324/309; 324/306, 600/413, 600/419
FIELD-OF-SEARCH: 324/306, 324/309, 324/307, 324/300, 128/653.3, 128/653.2

PRIOR-ART-DISCLOSED:

U.S. PATENT DOCUMENTS

PAT-NO	ISSUE-DATE	PATENTEE-NAME	US-CL
4718424	January 1988	Nishimura	324/306
4800889	January 1989	Dumoulin	324/309
4870361	September 1989	In Den Kleef et al.	324/307
5031624	July 1991	Mistretta et al.	324/306
5101156	March 1992	Pelc	324/306
5115812	May 1992	Sano et al.	324/306

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Magnetic Resonance Angiography, Nishimura, et al., IEEE TMI, MI-5, 140-151, 1986.
Real-time Flow Measurements Using Echo-Planar Imaging, Guilfoyle, et al., Magn. Reson. Med., 18, 1-18, 1991.
Cancellation Excitation for Angiography, Pauly, et al., Fifth SMRM, 70-71, 1986.
Robust Velocity Selective Excitation, Pauly et al., 6th SMRM, 27, 1987.
Quantitative Single-shot flow Velocity Imaging with Stationary Signal Suppression using Flow-selective Pulses, Pope et al., 10th SMRM, 96, 1992.
Encoding Velocity Information In NMR Images By Phase Tagging, Lee, et al., 10th SMRM, 812, 1991.
Direct Acquisition Phase Contrast Angiography, J. N. Lee, 10th SMRM, 818, 1991.
Flow Imaging By Stationary Spin Suppression, H. Lee, 10th SMRM, 1154, 1991.
Driven Equilibrium MR Angiography: A Study of Static Spin Suppression, Foster et al., 6th SMRM, 30, 1987.
GRASE Imaging: A Novel Fast MRI Technique, Oshio, et al., Magn. Reson. Med. 20(2):344-349, 1991.

ART-UNIT: 267
PRIMARY-EXAMINER: Tokar; Michael J.
ASSISTANT-EXAMINER: Mah; Raymond Y.
ATTY-AGENT-FIRM: Quarles & Brady

ABSTRACT:

An angiogram is produced using NMR fast pulse sequences in which the views are acquired in shots preceded by a preparatory pulse sequence. Each shot is acquired twice with differing preparatory pulse sequences and the resulting NMR data is subtracted to null the stationary tissues in the reconstructed image.

8 Claims, 6 Drawing figures

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